

Spatial distribution and formation of earthworm burrows

JARI HAUKKA

With one figure

(Accepted: 90-10-15)

1. Introduction

Earthworm burrow systems are among the most important components of large-size porosity in soil (LAVELLE, 1988). In clay soils especially there are only a few mechanisms that can form large, permanent pores, namely earthworms and plant roots. Ploughing for example is quite an ineffective way to form large pores and acts only on the upper layers. In modern agriculture heavy machines compact soil year after year, and as a result the soil under the ploughing layer become dense, water infiltration is prevented and this causes water logging and harms crop plants.

In burrows, which are usually lined with mucous deposits, water and air can flow quite rapidly. There is evidence that earthworm burrows could increase hydraulic conductivity by 80% and water infiltration sixfold (LEE, 1985). This large-pore burrow system provides extra drainage, and can be very important in preventing the formation of water ponds following heavy rain.

When functional simulation models of soil pore systems are constructed, there is a need to know the geometric and spatial patterns of the burrow systems. KRETZSCHMAR (1987) has developed an interesting simulation model, which shows how earthworm burrows partition soil. He assumed that burrows were randomly distributed in soil. However, the soil partitioning could be quite different, if burrows were distributed in aggregated or regular patterns.

In this study the spatial pattern of earthworm burrows was examined to get a better understanding of burrow systems and to make possible the building of more realistic simulation models.

2. Material and methods

Soil samples were taken in summer 1985 from two field trials. In a cultivation experiment three methods were compared [direct drilling (DR), normal ploughing (P), and harrowing (H)]. Treatments were replicated four times in blocks. In a soil structure experiment there were two factors both with two levels, which were replicated four times in blocks. The factors were tillage method (no tillage and glyphosate, or ploughing); and crop (fallow, or wheat). The soil in the fields was heavy clay.

The soil samples were taken by inserting plastic cylinders (diameter 30 cm) to a depth of 50 cm using a hydraulic machine. The samples were allowed to dry and several hydraulic conductivity measurements were carried out (AURA, unpublished). After the measurements the samples were stored in a dry place. In 1987 spatial pattern of biopores were studied. Samples were cut horizontally at depths of 20, 30 and 40 cm and the spatial patterns of biopores with diameter more than 2 mm were marked on plastic sheets placed on the cut surfaces. After marking the points were digitized.

The spatial patterns of the holes were analysed by plotting the RIPLEY's K statistic and its 95% confidence intervals (RIPLEY, 1981; TOMPPA, 1986). Only surfaces with 25 or more holes were analysed; the number of patterns analysed was 10. If the value of the statistic crossed the upper confidence limit first, the pattern was considered to be aggregated, and if the lower limit, regular. Randomness

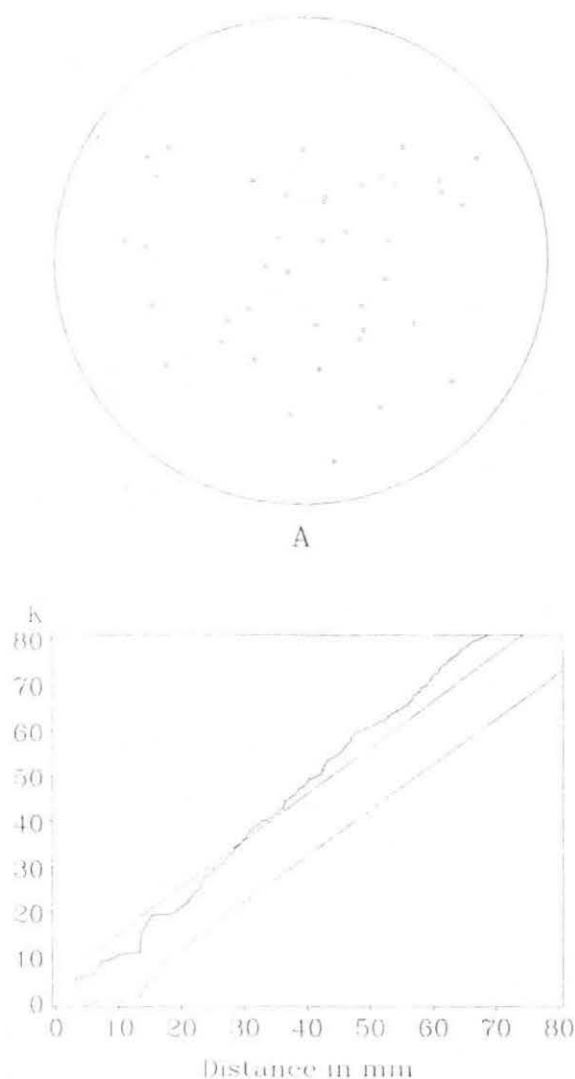


Fig. 1. Spatial pattern of biopores in a soil core from a reduced tillage wheat plot. (A) Section at 40 cm depth. (B) K statistic with 95% confidence limits.

was assumed if the statistic remained between the confidence limits. The total length of burrows in unit cubes was calculated with density estimates of holes by the equation of LANG and MELHUIJH (1970).

Experiments on burrow formation were carried out in the laboratory at 8 °C. A wooden frame was placed into a glass aquarium (75 cm × 50 cm × 40 cm) so that a 3 cm space was left between frame and glass. This space was filled with clay soil. The depth of the soil was 38 cm and the volume 28.5 dm³. At the beginning of the experiment the earthworms were placed on the surface and the aquarium was covered immediately with a black plastic sheet. The emerging earthworm burrows were marked on a transport plastic sheet, attached on the aquarium wall. The experiment was continued for seven days. At the end the coordinates of both ends of burrows as well as the lengths were measured. Two experiments were conducted with *Lumbricus terrestris* L. (10 specimens in each experiment) and four with *Aporrectodea caliginosa tuberculata* (SAV.) (16 specimens in each experiment).

From the burrow coordinates it was possible to calculate the angle between burrow direction and the horizontal; indices of straightness and mean depth of burrows were also calculated. The angular data were analysed using procedures described by BATSCHLET (1981).

3. Results and discussion

In figure 1 an example of biopore spatial pattern is presented with associated RIPLEY'S K. The pattern could be considered aggregated. Nine out of ten patterns analysed proved to be aggregated and one random. No pattern showed regular configuration. The mean distance to where K crossed the upper confidence limit was 31 mm (s.e. 8.1.). The interpretation of this distance is that points nearer each other than 31 mm are randomly distributed and the aggregation is seen only with large distances.

The length of biopores was calculated with the assumption of randomness of direction. If the biopores are more vertical, the estimates are too high, and if more horizontal, too low. The numbers and lengths of biopores were largest in low tillage soil (table 1). This correlates with higher earthworm biomasses in these treatments (HAUKKA, unpublished). However, the variation between treatments was so high that ANOVA could not show significant differences.

Table 1. Description statistics for biopores in soil cores.

Treatment	Mean abundance dm ²	S.E.	Mean length dm/dm ³	S.E.
Structure experiment				
Fallow with glyphosate	2.8	0.7	5.6	1.5
Fallow with ploughing	1.8	0.6	3.6	1.2
Wheat with reduced tillage	2.1	0.8	4.1	1.6
Wheat with ploughing	1.6	0.4	3.2	0.8
Direct drilling experiment				
Ploughing	1.9	0.8	3.9	1.7
Direct drilling	1.8	0.6	3.6	1.1
Harrowing	0.9	0.4	1.9	0.7

In the burrowing experiment, no differences in angular orientation of burrows could be found between species (table 2). The mean angles of both species were near zero and the parameter of concentration was quite low, thus no differences between species could be detected. Low concentration also shows weak orientation to any specific direction. On the basis of these data no conclusions could be drawn concerning the extent of horizontal burrowing.

No significant differences in mean depths of burrows could be found between species.

The mean length of new burrow formed by *A. c. tuberculata* was significantly higher (t-test 0.01) than that formed by *L. terrestris*. Comparison between estimates in table 2 and those presented by MARTIN (1982) is not directly possible. It must be taken into account that only about one third of the burrows in this study could be observed (the soil was 3 cm thick) and that the temperature was 12 degrees lower. Bearing these differences in mind, the results are quite near MARTIN'S (1982) observations.

Table 2. Statistic from the burrowing experiment.

Statistic	<i>A. c. tuberculata</i>		<i>L. terrestris</i>	
Number of burrows measured	400		75	
Mean angle	15.9		10.0	
Mean vector (r)	0.13		0.16	
Parameter of concentration (κ)	0.26		0.30	
Mean depth (mm)	74.5	(3.5)	89.9	(9.2)
Burrow formation (mm/d/g)	68.9	(8.0)	35.6	(6.8)

Angles are analysed assuming quadrimodality.

4. Conclusions

A. Large pores, which are mainly formed by earthworms and plant roots are spatially aggregated in soil.

B. The density and length of large-size pores varies depending on soil treatment method. Minimum tillage seems to provide higher density of large pores.

C. In laboratory experiments it is difficult to show differences between species in burrow formation behaviour. However, *A. c. tuberculata* forms new burrows more rapidly than *L. terrestris*.

5. Acknowledgements

This study was supported by the Academy of Finland as part of a project entitled "The role of soil macrofauna in field crop cultivation". I wish to thank Professor M. Markkula and Dr. V. Huhta for their support, Dr. E. Aura from the Department of Agricultural Chemistry and Physics for permitting the use of his samples in the study, and Mr. R. Ukkola for technical assistance.

6. References

- BATSCHLET, E., 1981. Circular statistics in biology. Academic Press, London.
- KRETZSCHMAR, A., 1987. Soil partition effect of an earthworm burrow system. *Biol. Fert. Soils* **3**, 121–124.
- LANG, A. R. G., F. M. MELHUIS, 1970. Lengths and diameters of plant roots in non-random populations by analysis of plane surfaces. *Biometrics* **26**, 421–431.
- LAVELLE, P., 1988. Earthworm activities and the soil system. *Biol. Fert. Soils* **6**, 237–251.
- LEE, K. E., 1985. Earthworms. Academic Press London, New York.
- MARTIN, N. A., 1982. The interaction between organic matter in soil and the burrowing activity of three species of earthworms (Oligochaeta: Lumbricidae). *Pedobiologia* **24**, 185–190.
- RIPLEY, B. D., 1981. Spatial Statistics. Wiley, N.Y.—Chichester—Brisbane—Toronto.
- TOMPPA, E., 1968. Models and methods for analysing spatial pattern of trees. *Comm. Inst. Forest. Fenniae* **138**.

Synopsis: Original scientific paper

HAUKKA, J., 1991. Spatial distribution and formation of earthworm burrows. *Pedobiologia* **35**, 175–178.

The spatial pattern of large-size pores (biopores) in clay soil samples was studied. The pattern was analyzed with RIPLEY's K-statistic. Pores were in most cases aggregated. The abundance of pores was highest in plots which were cultivated without ploughing.

In laboratory experiments of burrow formation there was no difference between earthworm species (*A. c. tuberculata* and *L. terrestris*) in burrow angular orientation or mean depth. However, *A. c. tuberculata* formed new burrows more rapidly.

Keywords: burrow formation; *Aporrectodea caliginosa tuberculata*; *Lumbricus terrestris*; spatial pattern

Address of the author: National Public Health Institute, Kallioliinantie 4, SF-00140 Helsinki, Finland.